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Evaluation of a transcutaneous carbon dioxide monitor (“TOSCA”) in adult patients in routine respiratory practice

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KEYWORDS
Transcutaneous carbon dioxide;
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Summary
Background: Non-invasive measurement of oxygenation is routine in adult clinical practice but transcutaneous monitoring of PCO_2 ($PtcCO_2$) is used much less due to technical difficulties with earlier transcutaneous electrodes.
Objective: Our aim was to determine the reliability of estimating arterial PCO_2 ($PaCO_2$) using a recently introduced combined $SaO_2/PtcCO_2$ monitor (“TOSCA”, Linde Medical Systems) in adult patients in routine clinical respiratory practice.
Methods: $PtcCO_2$ was measured in patients requiring arterial blood gases for clinical reasons. Ten minutes after the probe had been attached to an earlobe $PtcCO_2$ was recorded, immediately before arterial blood sampling. The PCO_2 values obtained were compared by Bland–Altman analysis.
Results: Samples were taken from 48 unselected patients with varied pathology. There were no technical problems. Median age was 56 years (range 20–86 years). The mean difference between $PaCO_2$ and $PtcCO_2$ was −0.04 kPa, SD of the difference 0.67 kPa. Bland–Altman analysis showed generally good agreement between the two measurements across the range of $PaCO_2$ values (4–10.9 kPa). Four of 48 measurements showed a PCO_2 difference >1 kPa with no technical or clinical explanations apparent.
Conclusions: The accuracy of estimation of $PaCO_2$ by the TOSCA transcutaneous electrode was generally good and the device appears promising for use in routine clinical respiratory practice.

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Introduction

Non-invasive estimation of arterial PCO_2 by measurement of transcutaneous carbon dioxide ($PtcCO_2$) has been possible since 1972 but for many years measurement of $PtcCO_2$ was inaccurate and impracticable with sensors being fragile and expensive and requiring frequent calibration.[1] More recent $PtcCO_2$ monitors have proved to be more reliable and are routinely used in infants but are not widely used in adult patients. If accurate they would usefully complement the 'gold standard' measurement of arterial blood gases which is invasive, intermittent and may be unpleasant. Preliminary studies of the reliability of a combined $PtcCO_2/SpO_2$ monitor (TOSCA, Linde Medical Sensors, Basel, Switzerland) have shown good agreement in adult volunteers and anaesthetised adults.[2–4] The current TOSCA sensor has been evaluated in anaesthetised children,[5] anaesthetised adults[6] and ill neonates[7] with all these studies again showing good agreement between $PtcCO_2$ and $PaCO_2$. However, one study involving acutely ill adult patients receiving intensive care[8] suggested a significant difference between measured $PtcCO_2$ and $PaCO_2$, but this study included only a small number of subjects ($n = 8$) with multiple measurements from individuals.

To our knowledge no studies have been reported evaluating the accuracy of the TOSCA monitor in adult patients in routine respiratory practice. We have therefore determined the reliability of estimating $PaCO_2$ using the TOSCA monitor in unselected adult patients in routine respiratory practice.

Methods

After approval from the Local Research Ethics Committee and obtaining informed patient consent, we prospectively enrolled 48 patients into the study. All were inpatients in a respiratory ward (including general and subspecialty respiratory medicine) who required arterial blood gas analysis for clinical reasons. A detailed technical description of how the TOSCA sensor works is provided elsewhere.[5] $PtcCO_2$ is measured (along with SpO_2) via a sensor attached by a low-pressure clip to an earlobe. The sensor probe heats the earlobe to 42 °C to enhance blood flow. After automated calibration the TOSCA sensor was attached to an earlobe to monitor $PtcCO_2$; after 10 min $PtcCO_2$ was recorded immediately prior to arterial blood sampling for blood gas analysis in the usual way (Gem Premier 3000, Instrumentation Laboratory, Lexington, MA, USA). Co variables recorded included inspired oxygen concentration, diagnosis, age, gender, heart rate, blood pressure, temperature and any technical problems with the measurement.

Statistical analysis

The level of agreement between $PaCO_2$ and $PtcCO_2$ measured by TOSCA was assessed by Bland–Altman analysis.[9]

Results

Forty-eight adult patients were recruited prospectively. Their median age was 56 years (range

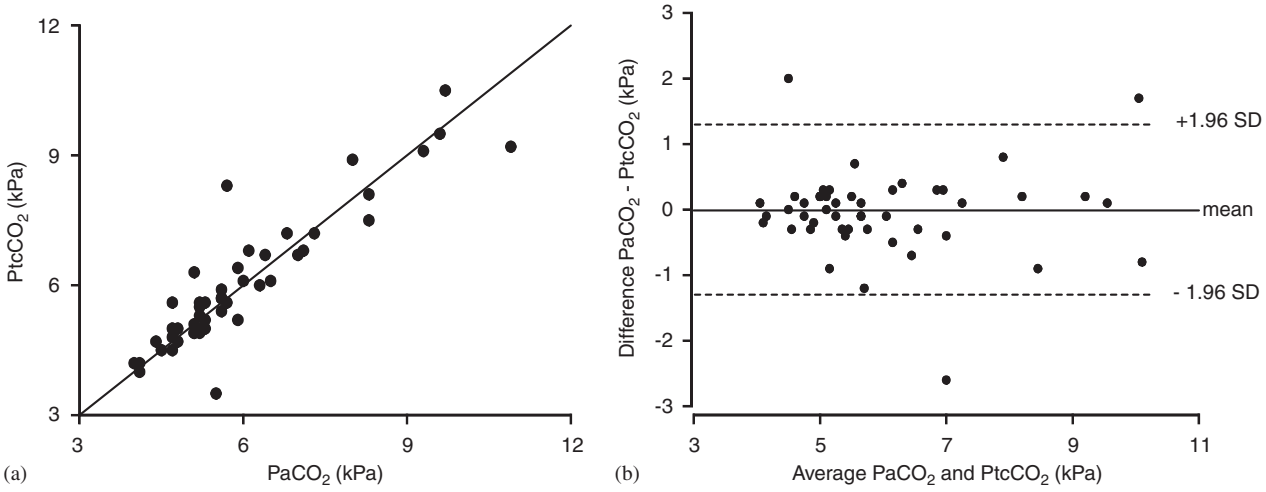

Figure 1 (a) Comparison of transcutaneous and arterial PCO_2 in 48 patients showing line of identity. (b) Bland–Altman plot of difference between 2 estimates of PCO_2 and their average.

Table 1 Individual $PaCO_2$ and $PtcCO_2$ values in 48 patients.

$PaCO_2$ (kPa)	$PtcCO_2$	Difference
5.9	6.4	−0.5
5.3	5	0.3
4.8	4.7	0.1
8.3	7.5	0.8
5.1	4.9	0.2
5.2	5.6	−0.4
7	6.7	0.3
6.5	6.1	0.4
9.7	10.5	−0.8
5.2	5	0.2
5.6	5.4	0.2
5.2	4.9	0.3
5.3	5.6	−0.3
4.7	4.8	−0.1
8.3	8.1	0.2
5.1	4.9	0.2
5.5	3.5	2
4.8	5	−0.2
4.7	5	−0.3
4.7	5.6	−0.9
9.6	9.5	0.1
5.6	5.7	−0.1
6.1	6.8	−0.7
5.2	5.3	−0.1
4	4.2	−0.2
6	6.1	−0.1
5.9	5.2	0.7
8	8.9	−0.9
4.5	4.5	0
4.7	4.5	0.2
7.3	7.2	0.1
4.4	4.7	−0.3
6.4	6.7	−0.3
7.1	6.8	0.3
5.7	8.3	−2.6
4.1	4.2	−0.1
5.3	5.2	0.1
5.7	5.6	0.1
5.2	5.5	−0.3
5.6	5.7	−0.1
5.1	6.3	−1.2
9.3	9.1	0.2
5.1	5.1	0
10.9	9.2	1.7
4.1	4	0.1
6.3	6	0.3
5.6	5.9	−0.3
6.8	7.2	−0.4

20–86). Subjects had a wide variety of diagnoses including; chronic obstructive pulmonary disease ($n = 20$), cystic fibrosis ($n = 9$), pulmonary fibrosis ($n = 5$), primary pulmonary hypertension ($n = 4$), bronchiectasis, extrinsic allergic alveolitis and chronic thromboembolic pulmonary hypertension ($n = 2$ each), acute pulmonary embolism, histiocytosis *X*, obliterative bronchiolitis and respiratory muscle weakness ($n = 1$ each). The group included both acutely ill and clinically stable patients and each patient was reported once only. Only 4 patients had an arterial pH < 7.35, all with chronic obstructive pulmonary disease. Mean difference between $PaCO_2$ and $PtcCO_2$ was −0.04 kPa with a standard deviation of the difference of 0.67 kPa. Bland–Altman analysis showed generally good agreement between the two measurements (Fig. 1(b)) across the range of $PaCO_2$ values recorded (4–10.9 kPa). Four of 48 measurements showed a PCO_2 difference of > 1 kPa. No technical problems were experienced (Table 1).

Discussion

We have evaluated the accuracy of the TOSCA sensor for non-invasive estimation of arterial carbon dioxide in adult patients in a general respiratory ward. Our results show generally good agreement between $PtcCO_2$ measured by TOSCA and $PaCO_2$ measured from sampling arterial blood. The monitor is simple to use and appears promising for use in adult respiratory practice within its limitations. Clearly, measurements of $PtcCO_2$ are not as informative as arterial blood gases (e.g. it does not measure pH or HCO_3^-) and isolated elevated CO_2 levels give an incomplete picture, for instance in patients with chronic type 2 respiratory failure. Measurements of $PtcCO_2$ should be used in conjunction with arterial blood gas measurement, particularly for following trends after an initial arterial sample has been taken, the main advantages being that it provides a continuous measurement and reduces the need for frequent invasive sampling of arterial blood. Our study did not assess the accuracy of the TOSCA monitor when used to follow trends in $PaCO_2$ over time as only one comparison was made. We chose to make one baseline comparison of $PaCO_2$ and $PtcCO_2$ because a large number of patients in the study required only a single arterial blood sample and to avoid the possibility of intrasubject variation confounding the analysis. Further studies examining the accuracy of the TOSCA sensor when used continuously over an extended time period are required.

A discrepancy of > 1 kPa between $PtcCO_2$ and $PaCO_2$ was seen in 4/48 subjects; the reason for this is unclear with no common factor apparent. As no repeat comparisons were made, it was not clear whether the discrepancies were consistent within individuals.

A weakness of this study is that most subjects were clinically stable with only 4/48 subjects having an arterial pH $<$ 7.35, although a wide range of PCO_2 values were recorded. Further studies assessing the accuracy and usefulness of the TOSCA sensor in patients with acute respiratory failure would be useful as this is the group of patients who may benefit most from using this device.

There have been concerns in the past regarding the safety of transcutaneous CO_2 monitors as heated probes have caused cutaneous blistering when used for prolonged periods. The manufacturer states that the probe is safe for continuous use as long as it is changed to the opposite ear every 12 h. We encountered no safety issues but we did not set out to investigate continuous monitoring over an extended time period. We conclude that the accuracy of the TOSCA sensor used in adult patients in routine respiratory practice is good and the device appears promising for use in this setting.

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